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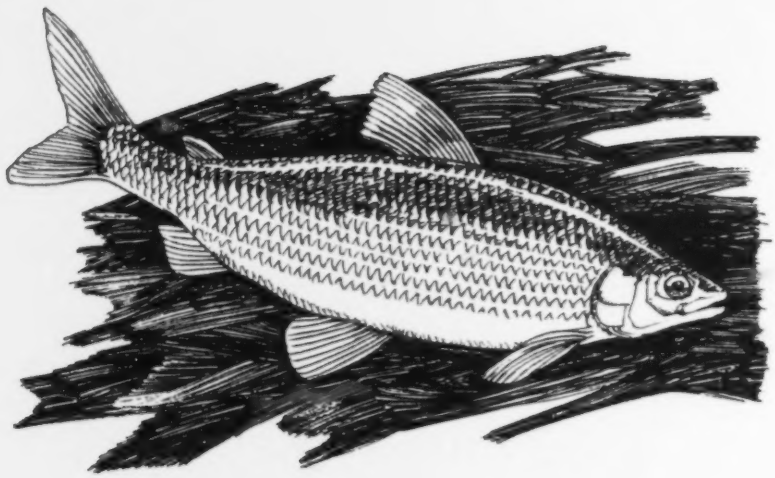
RESOURCE DATA AND SPECIES AT RISK SECTION

Shortjaw Cisco Species at Risk Assessment 2001



Alberta Species at Risk Report No. 82

Alberta
SUSTAINABLE RESOURCE DEVELOPMENT

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Shortjaw Cisco Species at Risk Assessment 2001

Mark Steinhilber

Alberta Species at Risk Report No. 82

February 2004

Project Partners:

Alberta
SUSTAINABLE RESOURCE DEVELOPMENT
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Alberta
COMMUNITY DEVELOPMENT

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TABLE OF CONTENTS

LIST OF FIGURES v

LIST OF TABLES v

ACKNOWLEDGEMENTS vi

EXECUTIVE SUMMARY vii

1.0 INTRODUCTION 1

1.1 Shortjaw Cisco Identification 3

2.0 STUDY AREA 4

3.0 METHODS 5

4.0 RESULTS 6

4.1 Relative Abundance of Cisco Populations 6
4.2 Morphology 7
4.3 Overview of Northeastern Alberta Ciscoes 12

5.0 DISCUSSION 13

6.0 MANAGEMENT IMPLICATIONS AND FUTURE DIRECTIONS 16

7.0 LITERATURE CITED 17

APPENDIX A. Cisco catch-per-unit-effort for sampling sites in northeastern Alberta and northwestern Saskatchewan in 2001. 20

APPENDIX B. Depth distribution of Lake Athabasca. 21

LIST OF FIGURES

Figure 1. The distribution of shortjaw cisco in North America. 2

Figure 2. Shortjaw cisco (upper) and lake herring (lower) from Barrow Lake, Alberta. ... 3

Figure 3. Cisco sampling sites in northeastern Alberta. 4

Figure 4. Gillraker number frequency histogram for Colin Lake cisco (n=51). 7

Figure 5. Length-at-age relationship for Colin Lake cisco (n=50). 7

Figure 6. Gillraker number frequency distribution for Andrew Lake cisco (n=61). 8

Figure 7. Age-length relationship for Andrew Lake cisco (n=37). 8

Figure 8. Gillraker number frequency distribution for Lake Athabasca ciscoes (n=146). . 9

Figure 9. Relationship between gillraker number and gillraker length for Lake Athabasca ciscoes. 10

Figure 10. Gillraker counts from ciscoes collected at various depths in Lake Athabasca.10

Figure 11. Gillraker number frequency distribution for Cold Lake ciscoes (n=52). 11

Figure 12. Age-length relationship for Cold Lake ciscoes (n=40). 11

LIST OF TABLES

Table 1. Number of cisco collected from all sites in northeastern Alberta 1996-2001. ... 12

Table 2. Gillraker counts from northern Alberta ciscoes. 13

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EXECUTIVE SUMMARY

The shortjaw cisco (*Coregonus zenithicus*) is considered *Threatened* in Canada (COSEWIC 2003) and has been approved for listing as *Threatened* in Alberta. The Alberta designation is based on the restricted distribution of this species in the province and its isolation from other populations. To date, it has been verified at only one locality – Barrow Lake in the Canadian Shield region north of Lake Athabasca – although unconfirmed reports have also come from Lake Athabasca, Gregoire Lake, and Cold Lake. The main objective of the work undertaken in 2001 was to search for other populations of shortjaw cisco in the province. Additional distribution data would assist in assessing the status of this species by providing 1) updated distribution data, 2) a search effort context in which to evaluate the number of reported element occurrences, and 3) a baseline for evaluation of future distribution trends. Previous work on the shortjaw cisco in Barrow Lake determined that this population appears stable and is under little immediate threat.

Colin Lake, Andrew Lake, and Lake Athabasca were surveyed in 2001. Two sites on Lake Athabasca were examined in detail. One area was located in Alberta along the southern shore just west of the Alberta-Saskatchewan border, the other was along the northwestern shore of Black Bay near Uranium City, Saskatchewan. Two hundred and ninety-nine ciscoes were captured at all three sites within Alberta. Colin Lake and Andrew Lake appear to contain morphologically similar dwarf forms of lake herring (*C. artedi*). Preliminary analysis suggests three forms or species of cisco may inhabit Lake Athabasca. One form is relatively large with many gillrakers, one is small with an intermediate number of gillrakers (the most abundant form), and one is small with few gillrakers. This latter form is believed to represent shortjaw cisco. Although about one-third of the ciscoes captured in the deeper water on the Saskatchewan side of the lake may be shortjaw cisco (the remainder being lake herring), only two specimens out of 50 cisco encountered on the Alberta side of the lake had gillraker counts indicative of this species. Further work is required to confirm the identity of these two individuals.

One hundred cisco specimens from Cold Lake were also analyzed. Ninety-nine of these were clearly lake herring; however, one specimen was unique in the sample. It had few gillrakers compared to the rest of the sample, an exceptionally short dorsal fin base, and an ovary in an unusually advanced state of development. This single specimen may represent a shortjaw cisco but further sampling in deep water in Cold Lake is required to confirm the presence of this species at this site.

Data collected since 1996 suggest shortjaw cisco are extremely rare in Alberta and should be managed accordingly. Future work should focus on confirming the identity of suspected shortjaw cisco in Cold Lake, the Alberta side of Lake Athabasca, and Gregoire Lake, and on the continued monitoring of the Barrow Lake population.

1.0 INTRODUCTION

The shortjaw cisco was designated *Threatened* in 1987 by the Committee on the Status of Endangered Wildlife in Canada, and that status was reconfirmed in 2003 (COSEWIC 2003, Todd (2003). The designation was based largely on a dramatic decline in populations of this species in the Great Lakes over the past half century (Todd 1985, Fleischer 1992, T. Todd, pers. comm.). This decline is believed to have resulted from a complex combination of commercial exploitation, sea lamprey predation, competition with introduced fishes, and hybridization and competition with other sympatric cisco species. In Alberta, shortjaw cisco has been approved for listing as *Threatened* under the *Wildlife Act* because of a restricted distribution in the province and isolation from other populations.

The distribution of shortjaw cisco outside of the Great Lakes basin extends throughout much of northern North America, from southeastern Ontario to Great Slave Lake (Scott and Crossman 1973, Lee et al. 1980). Although the extent of occurrence (IUCN 2001) of this species is large – approximately 1.5 million km^2 (Steinhilber 2002) - the actual area of occupancy within this range (i.e., the number of lakes in which it is known or believed to occur) appears to be small (Figure 1). There is a great deal of uncertainty regarding the actual distribution of shortjaw cisco in northern Canada. Much of this area is remote and many of the hundreds of thousands of lakes that dot the landscape have not been surveyed. To complicate matters, the taxonomy of shortjaw cisco remains questionable despite considerable effort directed toward unraveling the evolutionary history and distinguishing characteristics of this species. Given that specialists in shortjaw cisco taxonomy must exercise caution when identifying this species, it is reasonable to suspect that shortjaw cisco are often misidentified when encountered incidentally in projects focused on other species (see shortjaw cisco identification below). As a result, the size of the shortjaw cisco genetic reservoir in northern North America is virtually unknown. Yet these data are critical for an accurate assessment of rarity and global extinction risk.

In Alberta, shortjaw cisco are known to occur in only one location - Barrow Lake – in the Canadian Shield region of northeastern Alberta (Paterson 1969, Nelson and Paetz 1992, Steinhilber et al. 2002) (see Figure 3). Reports of this species from the Alberta side of Lake Athabasca (Dymond and Pritchard 1930), Gregoire Lake (Tripp and Tsui 1980), and Cold Lake (Clarke 1973) are unverified and remain questionable. The number of occurrences of a species in a particular jurisdiction is an important criterion in schemes developed to assess extinction risk (e.g., World Conservation Union [IUCN] criteria). Yet these numbers may have little meaning in the absence of some indication of search effort. The importance of including a *per-unit-search effort* component will vary among species depending on such things as accessibility of the species' habitat, its habits or biological attributes (secretive, cryptic coloration), and its importance to humans. Populations of species that coexist in close proximity to human habitation, are easy to detect, or have been studied intensively, might be estimated and tracked reasonably by simply counting number of occurrences. However, populations of species that occur primarily in remote areas are difficult to detect (or identify), or have not been studied in detail may be vastly underestimated if based on reports from chance encounters or incidental captures in

Figure 1. The distribution of shortjaw cisco in North America.

general biological inventories. For these species, targeted inventory and monitoring strategies, employed in carefully selected locations and habitats, may be essential for gathering the baseline data needed for an accurate assessment of distribution, abundance, population trend, and extinction risk. Search effort, in these cases, becomes a critical component of the *number of occurrences* criterion that will figure prominently in management decisions and recovery planning. Therefore, the primary objective of this study was to sample as many lakes as possible in northeastern Alberta, using the best

available knowledge of shortjaw cisco biology and taxonomy, to search for other populations of this fish. There were no *a priori* reasons to expect to find additional populations in this area. In this context, the data are equally valuable whether the species was present or absent at any site. The value of the work lies in providing a *search effort* framework upon which *number of occurrences* can be evaluated to provide the most accurate risk assessment possible.

1.1 Shortjaw Cisco Identification

Two species of cisco are known to occur in Alberta (Nelson and Paetz 1992). One is the widespread and common cisco or lake herring, *Coregonus artedi* (LeSueur 1818), the other is the shortjaw cisco, *C. zenithicus* (Jordan and Evermann 1909) (Figure 2). Taxonomic uncertainty has plagued the shortjaw cisco since it was first described early last century. Neither morphological nor molecular analyses have yet provided conclusive markers that are diagnostic of this highly plastic and adaptable species at all known sites throughout its range. For now many species of cisco are best identified by counting the number of gillrakers on the first gill arch. Gillrakers are slender bony protuberances on the gill arches that presumably function in the retention of planktonic food items. They are believed to be under genetic control (Svardson 1952) and are widely accepted as a valid trait in coregonine taxonomy.

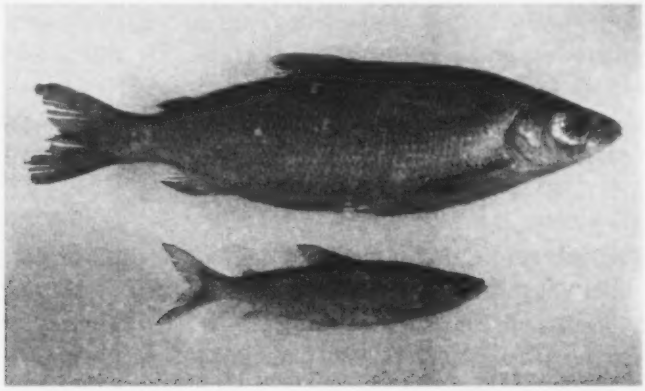

Figure 2. Shortjaw cisco (upper) and lake herring (lower) from Barrow Lake, Alberta.

The full range of gillraker counts for shortjaw cisco is 30 - 46 (Scott and Crossman 1973, Steinhilber 2000, Steinhilber et al. 2002); however, 98% of specimens examined by the author from across North America (n=122) had 44 gillrakers or fewer (Steinhilber 2000). Gillraker counts in lake herring can range from 38 to 64 (Scott and Crossman 1973); however, 98% of Alberta specimens examined (n=665) exhibited 42-59 gillrakers (M. Steinhilber, unpublished data). Usually, shortjaw cisco can also be distinguished from lake herring by their longer snout, shorter gillrakers, shorter dorsal fin base, longer upper jaw, lower jaw that does not extend beyond the upper jaw, and more vertical upper jaw tip (premaxillary bones) (Todd and Smith 1980). In addition, shortjaw cisco in Barrow Lake, Alberta can be separated from co-occurring lake herring by their larger size, shallower head, smaller eye, and longer dorsal fin (Steinhilber 2000). Caution must be

exercised when attempting to identify ciscoes based on one or a few characters because morphological plasticity and local adaptation have produced a great deal of variation in this group. All Alberta cisco populations with average gillraker counts less than 43 should be examined carefully and voucher specimens should be retained for future analysis and verification of identity.

2.0 STUDY AREA

The 2001 study sites are shown as closed circles in Figure 3. Three lakes in the Canadian Shield region were surveyed – Andrew Lake, Colin Lake, and Lake Athabasca. Two areas on Lake Athabasca were sampled. One extended along the southern shore of the lake from the Alberta-Saskatchewan border west to Point Brule; the other encompassed

Figure 3. Cisco sampling sites in northeastern Alberta. Closed circles represent lakes surveyed in 2001. Open circles are sites surveyed between 1996 and 2000 (Steinhilber 2000, Steinhilber and Rhude 2001). 1) Barrow Lake, 2) Ryan Lake, 3) Bocquene Lake, 4) Myers Lake, 5) Unnamed Lake # 1, 6) Daly Lake, 7) Darwin Lake, 8) Wylie Lake, 9) Winnifred Lake, 10) Unnamed Lake #2, 11) Fletcher Lake, 12) Dawson Lake, 13) Bayonet Lake, 14) Burstall Lake, 15) Leland Lake, 16) Andrew Lake, 17) Colin Lake, 18) Lake Athabasca south shore.

the northwestern shore of Black Bay near Uranium City, Saskatchewan (not shown on map). The habitats at these sites were dramatically different. All of the net placement locations in Alberta were characterized by relatively shallow water (8 m or less) over a featureless sandy substrate. The terrestrial habitat in this area is dominated by stabilized sand dunes that extend to the water margin. The terrain in the Black Bay area is typical of the Canadian Shield region – exposed bedrock and rugged topography. The aquatic habitats are varied with shallow shorelines and bays descending rapidly to deep regions with rock and silt substrates. Most of the net placement locations in this area included water depths in excess of 20 m; the deepest site sampled was 45 m.

A sample of 100 cisco specimens was acquired from staff of Alberta Sustainable Resource Development (SRD) as a by-product of a Lake Trout survey conducted at Cold Lake in east-central Alberta. Cold Lake is one of the deepest lakes in the province (Mitchell and Prepas 1990) and might be expected to contain suitable deep-water habitat for shortjaw cisco. However, the survey by SRD staff in June of 2001 focused on the littoral zone (Wes English, pers. comm.) and may have missed much of the most promising shortjaw cisco habitat.

3.0 METHODS

Study sites in northeastern Alberta and northwestern Saskatchewan were accessed by float plane from Fort Smith, NT. All fishes were collected by gill-netting over a three to six day period at each lake. Net sets were comprised of one 60 m multi-mesh net with six 10 m panels ranging from 10 to 25 mm bar mesh and a 60 m net with six 10 m panels of 10 – 50 mm bar mesh. All nets were 1.8 m in depth. The two nets were fished in series on the bottom of the lake.

No cisco were captured in mesh sizes greater than 30 mm. Therefore, catch-per-unit-effort (CUE) calculations did not include the area of net that was found to be unsuitable for capture of the target species (i.e., the 10 m panels of 40, 45 and 50, mm mesh). Of the 120 m of net set at each site, only 90 m was used to calculate the area of net fished (90 m long X 1.8 m deep = 162 m^2 of net of suitable size for capture of cisco). This calculation was used at all sites. Note that the values presented herein will not be directly comparable to CUE data acquired from other lakes in the study area in previous years as the mesh sizes of nets used in 2001 were different from previous years. The smallest nets used in 1996, 1997, and 2000 were 18.75 mm bar measure. Many of the ciscoes captured in 2001 were caught in mesh sizes smaller than 18.75 mm. It is possible that some forms of cisco may have been missed in earlier sampling due to a lack of small mesh gear (e.g., Burstall Lake, see Steinhilber and Rhude 2001).

Specimens for morphological analysis were either fixed in formalin or frozen immediately after initial processing in the field. Lengths and weights were taken for all fishes captured, and tissue samples (muscle) were excised from a sub-sample of specimens prior to fixation. Fixed specimens were subsequently transferred to 70% ethanol and deposited into the research collection at the Provincial Museum of Alberta. A

sub-sample of frozen specimens was transferred to the Freshwater Institute, Fisheries and Oceans Canada in Winnipeg for detailed morphological and genetic analyses (see Murray and Reist 2003).

Quantitative taxonomic analysis of the ciscoes captured was limited to enumeration of gillrakers on the first, left branchial arch of a random sample of preserved specimens. The number of gillrakers is the most important morphological character currently used in cisco taxonomy. Population modes and ranges are often cited as evidence for a species' identity. All rakers, including bony rudiments, on the upper (epibranchial) and lower (ceratobranchial) arch were counted under magnification. Data were examined graphically for any evidence of multi-modality in gillraker number within lakes that would suggest the presence of sympatric (co-occurring) populations.

Several external characters were evaluated qualitatively to assist in species identification. Upper jaw length, gillraker length, orbit diameter, and head depth have been shown to be useful in distinguishing lake herring from shortjaw cisco (Steinhilber 2000, Steinhilber et al. 2002). These traits were used in conjunction with gillraker number to support the identifications. Gillraker lengths were measured by staff of Fisheries and Oceans Canada from a subset of Lake Athabasca specimens. A quantitative assessment of the relationship between gillraker number and gillraker length for this sample was conducted after removing the effect of differing overall body size by dividing gillraker length by fork length.

Data on the age structure of the cisco populations was acquired by microscopic examination of otoliths following Mackay et al. (1990) and Stevenson and Campana (1992). Ages were not validated. Data from this study will be stored in the Fisheries Management Information System database (FMIS; maintained by the Fish and Wildlife Division, SRD) and in the collections database at the Provincial Museum of Alberta.

4.0 RESULTS

4.1 Relative Abundance of Cisco Populations

Two hundred and ninety nine ciscoes were captured at three lakes in northeastern Alberta in 2001. As expected, the number of ciscoes captured at each net placement site varied within lakes and was likely dependent on the characteristics of the micro-habitat at each location (Appendix A). However, some generalities are apparent from the data. Andrew Lake and Colin Lake support good populations of lake herring (see Morphology below). The species is apparently abundant in suitable, deep-water habitats. In Lake Athabasca most ciscoes were found in water deeper than about 8 m. Rarely were cisco encountered in shallow water, but at greater depths they appeared to be relatively common. Given the depth distribution of Lake Athabasca (Appendix B), it is likely that the majority of the area in Alberta does not contain suitable cisco habitat.

4.2 Morphology

4.2.1 Colin Lake

The gillraker number frequency distribution for Colin Lake cisco shows an approximately normal, unimodal pattern suggesting a single species or form of cisco in this lake (Figure4). The modal gillraker count for a sample of 51 specimens was 44 with a range from 41-48. These values suggest the cisco in Colin Lake are lake herring. This population can be characterized as a dwarf form of this species, exhibiting a mean fork length of 126 mm (range 101-183; n=74). The age-length relationship for this population (n=51) is shown in Figure 5. The slope of the line of best fit to these data is 6.43.

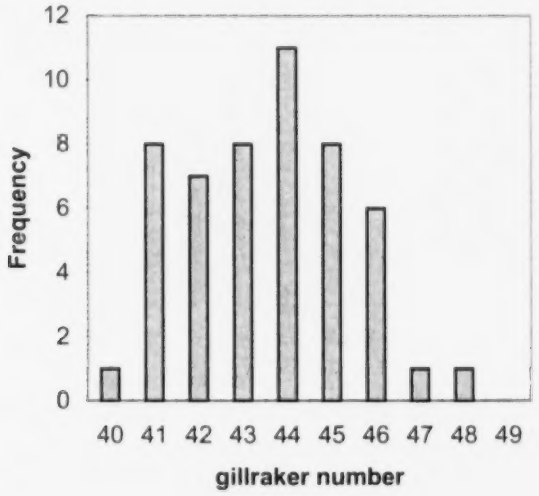

Figure 4. Gillraker number frequency histogram for Colin Lake cisco (n=51).

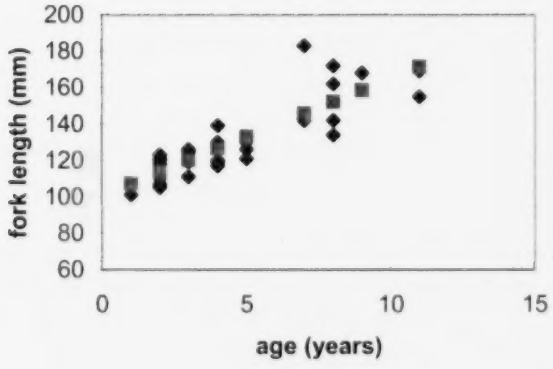

Figure 5. Length-at-age relationship for Colin Lake cisco (n=50).

4.2.2 Andrew Lake

As in Colin Lake, the gillraker frequency distribution for Andrew Lake cisco exhibits a normal, unimodal pattern (Figure 6). This is indicative of a single population in the lake. These data are supported by a similar gillraker distribution reported by Steinhilber (1990) from samples collected in 1988. The modal gillraker number for a sample of 61 specimens analyzed in the current study was 42 (range 39-46). Although the low end of this range overlaps with the range of shortjaw cisco gillraker counts in Barrow Lake and across North America, the modal value suggests this population represents *C. artedi*.

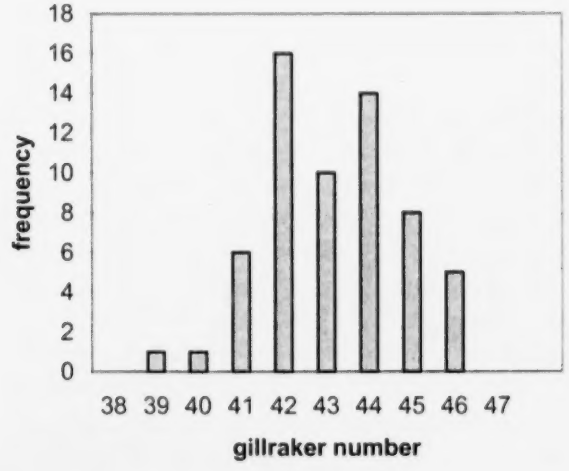

Figure 6. Gillraker number frequency distribution for Andrew Lake cisco (n=61).

Andrew Lake cisco can be described as a dwarf form. The mean fork length for a sample of 115 specimens was 120 mm (range 104-185). The age-length relationship for this population (n=37) is shown in Figure 7. The slope of the line of best fit to these data is 5.58, suggesting a similar growth rate to the Colin Lake cisco.

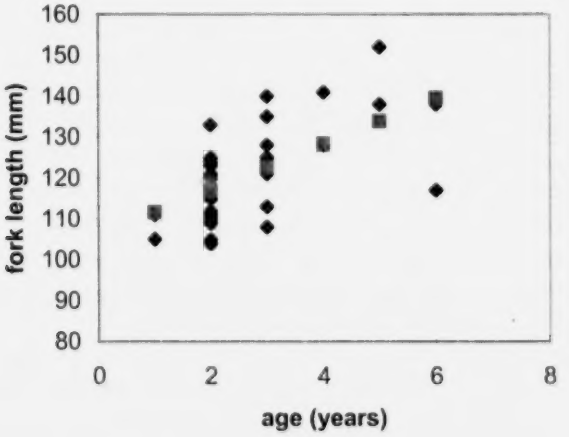

Figure 7. Age-length relationship for Andrew Lake cisco (n=37).

4.2.3 Lake Athabasca

The gillraker number frequency distribution (Figure 8) suggests three forms of cisco may occur sympatrically in Lake Athabasca. The most common form exhibits a modal gillraker count of 42. A second form has many gillrakers (mode = 53) and a third form has relatively few gillrakers (mode= 37). Some members of this latter group are believed to be shortjaw cisco. Sixteen individuals from a sample of 146 ciscoes exhibited gillraker counts of 37 or fewer. With the data available at this time, it is not possible to determine the exact point of separation between these low gillraker specimens and the common form with a modal gillraker count of 42.

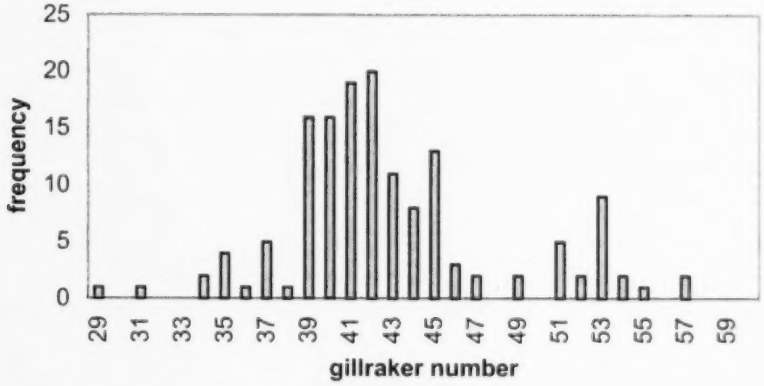

Figure 8. Gillraker number frequency distribution for Lake Athabasca ciscoes (n=146).

Most of the specimens with few gillrakers also had relatively short gillrakers. Figure 9 shows the relationship between gillraker number and gillraker length (GL) (see methods section for explanation of data transformation). The distribution reveals that most low gillraker specimens had shorter rakers than individuals with numerous rakers. This combination of few and short gillrakers is a key characteristic of most populations of shortjaw cisco in North America (Steinhilber 2000, Todd and Steinhilber 2002). With the exception of two individuals, all ciscoes with gillraker counts < 40 were captured at water depths of 20 m or more on the Saskatchewan side of the lake (Figure 10).

This deep-water habitat is consistent with most shortjaw cisco populations throughout North America, including the type locality of Lake Superior. Although there are exceptions (e.g., Barrow Lake & Lake Nipigon, MB), within a given lake the pattern of deep water vs. shallow water preference seems consistent. Since most of Lake Athabasca in Alberta is much shallower than 20 m (Canadian Hydrographic Service 1978), it is likely that this area contains little suitable shortjaw cisco habitat. Two specimens with 37 and 39 gillrakers (i.e., in the shortjaw cisco range) were captured in 8 m of water on the Alberta side of the lake. Although both had gillrakers shorter than the sample mean (GL/FL = 0.03233 and 0.034 respectively; mean =0.03875; n = 66), analysis of additional characters is needed to determine conclusively if these two individuals are truly distinct from the rest of the sample and if they represent shortjaw cisco.

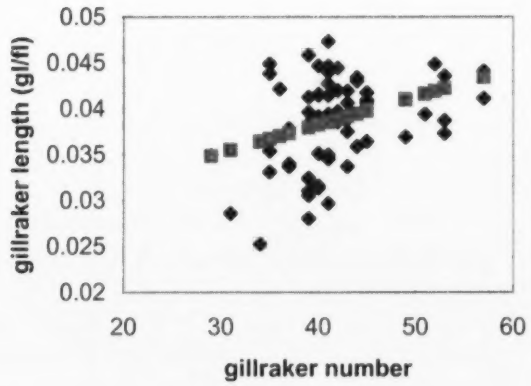

Figure 9. Relationship between gillraker number and gillraker length for Lake Athabasca ciscoes. Most of the low gillraker specimens had relatively short gillrakers compared to the high gillraker individuals.

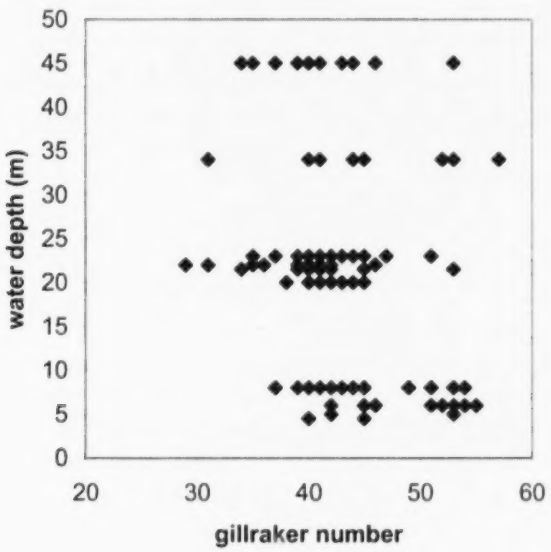

Figure 10. Gillraker counts from ciscoes collected at various depths in Lake Athabasca. Most of the low gillraker specimens (<40 rakers) were captured at depths >20m.

4.2.4 Cold Lake

The gillraker frequency distribution for a sub-sample of Cold Lake ciscoes is shown in Figure 11. The majority of the specimens analyzed represented *C. artedi* as indicated by a modal gillraker count of 48. However, one individual had 39 gillrakers, an extraordinarily short dorsal fin base (8 principal fin rays vs. 11-12 for the rest of the sample), and exhibited an ovary in an advanced state of development (large ova). All specimens were collected in mid-June and, with the exception of this individual, had gonads in an early

stage of development (e.g., ova barely visible to the naked eye). This specimen was obviously distinct from the rest of the sample and may be a shortjaw cisco based on the low gillraker count.

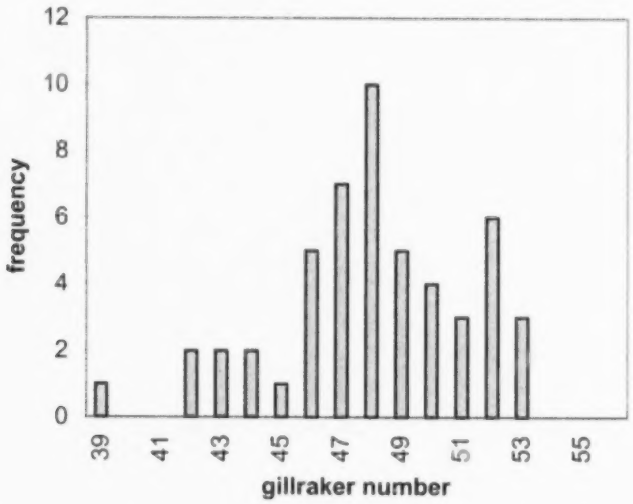

Figure 11. Gillraker number frequency distribution for Cold Lake ciscoes (n=52).

The majority of the cisco in Cold Lake can be described as a rather small but otherwise unremarkable form of lake herring. The mean fork length for the entire sample of 100 specimens was 176 mm (range 152-213). The putative shortjaw cisco specimen was the smallest specimen analyzed (fork length 152 mm; weight 35.4 g). The age-length relationship for a subset of this population (n=40) is shown in Figure 12. The line of best fit to these data has a slope of 6.44. The lack of specimens in the sample under three years of age likely reflects the gear used for surveying a lake trout population (i.e., larger mesh sizes).

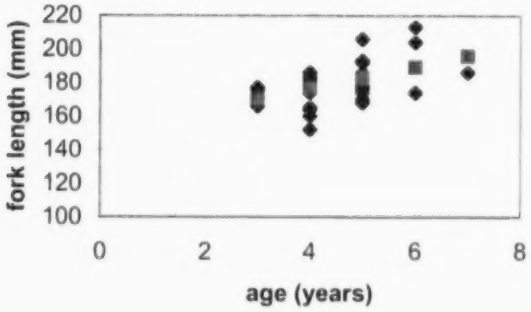

Figure 12. Age-length relationship for Cold Lake ciscoes (n=40).

4.3 Overview of Northeastern Alberta Ciscoes

Since 1996, 17 lakes in the Canadian Shield region and one lake in east-central Alberta have been surveyed in search of shortjaw cisco. A total of 1739 cisco specimens were collected over this time period; 42 of these (all from Barrow Lake) are believed to be shortjaw cisco, the remainder are a diverse assemblage of lake herring forms (Table 1). The key identifying character of gillraker number for each population is shown in Table 2. Ryan Lake contained two very distinct sympatric forms of lake herring – a small low gillraker form (lgr) and a large high gillraker form (hgr). Two sympatric forms were also identified in Unnamed Lake #1, Winnifred Lake, and Bocquene Lake based on characters other than gillraker number (see Steinhilber 2000 and Steinhilber and Rhude 2001). Populations from these latter three sites exhibited a unimodal gillraker number distribution and are combined in Table 2. Only two distinct groups are identified from Lake Athabasca, a high gillraker group (hgr) and a lower gillraker group (lower gr) suspected of comprising two subgroups. Individuals with the lowest gillraker counts are believed to be shortjaw cisco. However, the exact demarcation point between this species and the more common lake herring is still uncertain, so the group is presented here as a single unit. Two individuals from the Alberta side of Lake Athabasca and one specimen from Cold Lake may represent shortjaw cisco based largely on these counts. However, further taxonomic analysis of a larger sample is required before conclusions can be drawn regarding the identity of these specimens.

Table 1. Number of cisco collected from all sites in northeastern Alberta 1996-2001.

Lake	**Number of cisco collected**	**Lake (con't)**	**Number of cisco collected (con't)**
Andrew Lake	149	Dawson Lake	7
Barrow Lake		Fletcher Lake	204
C. artedi	388	Lake Athabasca	50
C. zenithicus	42	Leland Lake	4
Bayonet Lake	38	Myers Lake	132
Bocquene Lake	88	Ryan Lake	78
Burstall Lake	0	Unnamed Lake #1	89
Cold Lake	100	Unnamed Lake #2	13
Colin Lake	100	Winnifred Lake	146
Daly Lake	83	Wylie Lake	10
Darwin Lake	18		
		Total *C. artedi* sampled	1697
		Total known *C. zenithicus* sampled	42

Table 2. Gillraker counts from northern Alberta ciscoes.

Lake	(n)	Modal gillraker count	Range of gillraker counts
Andrew Lake	61	42	39-46
Barrow Lake - *artedi*	50	48	44-53
Barrow Lake - *zenithicus*	42	40	35-43
Bayonet Lake	28	46	42-50
Bocquene Lake	31	53	49-57
Cold Lake	52	48	39-53
Colin Lake	51	44	40-48
Daly Lake	21	51	48-57
Darwin Lake	12	43	41-48
Dawson Lake	6	45	41-45
Fletcher Lake	39	45	42-50
Lake Athabasca (hgr*)	15	53	49-55
Lake Athabasca (lower gr)	31	42	37-46
Leland Lake	3	N/A	50-55
Myers Lake	21	51	45-53
Ryan Lake (hgr*)	37	56	49-62
Ryan Lake (lgr*)	13	45	44-48
Unnamed Lake #1	45	47	42-55
Unnamed Lake #2	13	48	48-52
Winnifred Lake	58	45	39-48
Wylie Lake	10	46	42-49

* lgr = low gillraker form; hgr = high gillraker form

5.0 DISCUSSION

No new populations of shortjaw cisco were found in any of the 15 lakes surveyed in the Canadian Shield region of Alberta north of Lake Athabasca. Despite an enormous diversity of cisco forms among sites (Steinhilber 2000, Steinhilber and Rhude 2001) none is morphologically similar to the shortjaw cisco in Barrow Lake or to other shortjaw cisco populations across North America. This assessment is based primarily on the key character of gillraker number (see Table 2) but also includes quantitative and qualitative analyses of additional characters believed to be useful in distinguishing shortjaw cisco from other species (Koelz 1929, Steinhilber 2000).

Preliminary analysis suggests there may be three forms or species of cisco inhabiting Lake Athabasca. A form with many gillrakers stands out clearly in frequency distributions of gillraker counts. Despite this distinctiveness, the modal gillraker count suggests this is a form of lake herring. Sympatric forms of lake herring are not uncommon, having been found in a number of Alberta lakes including Ryan Lake,

Winnifred Lake, and an unnamed lake in the Canadian Shield area. The specific isolating mechanisms that lead to the divergence of these forms and the maintenance of distinct populations at each site have not been studied in detail, but differences in spawning time and place are likely involved.

Approximately one-third of the ciscoes captured on the Saskatchewan side of Lake Athabasca exhibited gillraker counts within the range of shortjaw cisco. The difficulty with this sample involves determining the demarcation point between the lake herring and shortjaw cisco. In Figure 8, values for the "low gillraker" cluster appear skewed toward lower counts but there is no disjunction or obvious second mode in this distribution. While either of these features would simplify the analysis, the distribution seen in Figure 8 is what would be expected if one population were rare relative to the other. In fact, the distribution of the Lake Athabasca sample is similar to that observed after the first year of sampling at Barrow Lake (Steinhilber 2000). The relatively rare shortjaw cisco, were represented as the portion of a distribution skewed toward lower gillraker counts. Only after several years of sampling did an obvious bimodality become evident.

Gillraker counts in the low- to mid-thirties have not been reported for lake herring anywhere in their range (Scott and Crossman 1973). It is possible that measurement error (inaccurate gillraker counts) may account for some of the low values reported in the present study. The quality of the specimens analyzed was somewhat variable and may have contributed to a certain amount of inconsistency regarding the ease at which gillrakers were enumerated. However, the substantial number of Lake Athabasca ciscoes with gillraker counts below 40 (n=39) suggests that measurement error is an unlikely explanation for all of the observed low values. It seems more likely that further analysis using independent data sets (including molecular data) will reveal the unique combination of characters that define the shortjaw cisco in Lake Athabasca and discriminate them from sympatric lake herring. Work to this end is currently being conducted in a joint project between the Provincial Museum of Alberta and Fisheries and Oceans Canada. For now, the available data suggest that shortjaw cisco do, in fact, occur in Lake Athabasca as reported by Dymond and Pritchard (1930), although their status on the shallow Alberta side of the lake remains questionable.

Logistic constraints precluded sampling of a wide range of habitats on the Alberta side of Lake Athabasca in 2001. Areas with water depths of 16-18 m are reported to exist within provincial boundaries (Canadian Hydrographic Service 1978, Mitchell and Prepas 1990, Appendix B). However, all of the areas sampled in 2001 were in much shallower water than this. Future sampling in deeper regions may reveal a cisco assemblage different from that reported here – perhaps one including a significant population of shortjaw cisco on the Alberta side of the border. A further consideration is the spatial distribution of Lake Athabasca cisco during the winter months. There appears to be no data on this subject, but it is possible that as thermal stratification diminishes and physiological temperature constraints are relaxed, cisco may expand their range into shallower water. If so, this could result in a seasonal immigration into Alberta. Such a possibility is only speculative, but may be worthy of further investigation.

Some evidence was found to support the possible existence of shortjaw cisco in Cold Lake as first suggested by Clarke (1973). Most of the specimens analyzed in 2001 represent an unremarkable form of lake herring. However, a single low gillraker specimen was found that may be a shortjaw cisco. This suggestion relies heavily on the distinct discontinuity between gillraker counts for the majority of the sample and this individual. The gap between 39 gillrakers and the remainder of the essentially normal distribution (Figure 11) suggests a demarcation between two forms. This is unlike the situation in Andrew Lake or Colin Lake where gillraker counts of 39-40 appear to represent the lower tails of normal, unimodal distributions of lake herring samples that simply overlap slightly with the known gillraker range of shortjaw cisco. It is possible that analysis of a larger sample may "fill in the gap" between this distinct individual and the rest of the Cold Lake sample, but this seems unlikely given the other unique characteristics of this specimen (well developed ova and a short dorsal fin base). It is important to note that early gonad maturation and a short dorsal fin base do not necessarily corroborate an identification of shortjaw cisco. However, Steinhilber (2000) found that shortjaw cisco typically have a shorter dorsal fin base than lake herring and that the shortjaw cisco paratype had the shortest dorsal fin base of any cisco specimen he examined. Interestingly, the shortjaw cisco in Barrow Lake had an unusually long dorsal fin base (Steinhilber 2000). This feature appears to be subject to phenotypic plasticity and/or local adaptation rendering its validity as a distinguishing character uncertain. Nevertheless, this is a unique specimen and further assessment of the Cold Lake cisco fauna seems warranted.

Future sampling in Cold Lake should concentrate on deep-water sites (e.g., 20 m or deeper), as this is the typical habitat of shortjaw cisco throughout most of its range (Clarke 1973, Scott and Crossman 1973). The single shortjaw-like individual found in the 2001 sample may represent a straggler into the littoral zone where the SRD Lake Trout survey was focused. Alternatively, it may simply represent an anomalous specimen of *C. artedi*. Little can be concluded at this time based on a sample size of one.

6.0 MANAGEMENT IMPLICATIONS AND FUTURE DIRECTIONS

The surveys conducted since the mid-1990s confirm that the shortjaw cisco is rare in Alberta. It now seems clear that this species is, at the very least, distributed very sporadically in the province and may well occur only in Barrow Lake as first reported by Paterson (1969). This population appears stable and is under little immediate threat (Steinhilber and Rhude 2001). Putative shortjaw cisco specimens acquired from Lake Athabasca and Cold Lake in 2001 may corroborate historical reports of this species at these sites, but further investigation is required to confirm specific identities. In 2003 the shortjaw cisco was approved for listing as *Threatened* in Alberta.

Future shortjaw cisco investigations should focus on the following:

- Confirmation of the identity of the low gillraker ciscoes in Lake Athabasca and Cold Lake. This will require additional sampling at both sites and a detailed examination of characters independent of gillraker number. Genetic and osteological analyses may be useful in corroborating identifications based on traditional external morphology.

- Verification of the occurrence of a population of low gillraker cisco in Gregoire Lake as reported by Tripp and Tsui (1980). Specimens should be subjected to the same detailed multi-character analysis as all putative Alberta shortjaw cisco samples.

- Population trends of the shortjaw cisco in Barrow Lake should be monitored via standard gill-netting protocols at 5-year intervals as suggested by Steinhilber and Rhude (2001).

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APPENDIX A. Cisco catch-per-unit-effort for sampling sites in northeastern Alberta and northwestern Saskatchewan in 2001.

Lake and Site	Depth fished (m)	Total # hours	Total # of Cisco captured	Cisco captured/100 m^2 of net/hour
Lake Athabasca (AB)				
1	5	21.50	1	0.029
2	5	23.75	0	0
3	6	23.50	8	0.210
4	6	21.00	3	0.088
5	4.5	35.50	2	0.035
6	8	36.00	36	0.617
All sites		161.25	50	0.191
Lake Athabasca (SK)				
1	21	24.00	57	1.466
2	22	28.00	34	0.750
3	23	27.00	30	0.686
4	34	18.50	15	0.500
5	20	7.50	12	0.988
6	23	20.50	10	0.301
7	45	24.50	21	0.529
All sites		150.00	179	0.737
Andrew Lake (AB)				
1	22	16.25	18	0.684
2	32	16.50	10	0.374
3	18	47.50	63	0.819
4	12.5	45.50	58	0.786
All sites		125.75	149	0.731
Colin Lake (AB)				
1	24	16.25	1	0.038
2	17	17.00	26	0.944
3	17	23.00	41	1.100
4	19	22.50	32	0.878
All sites		78.75	100	0.784

APPENDIX B. Depth distribution of Lake Athabasca (from Mitchell and Prepas 1990). Depths are in metres.

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